



JOINT STRIKE  
FIGHTER



# Prognostics and Health Management: *The Cornerstone of Autonomic Logistics*

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JSF PO PHM Development Leads

The Next Generation Strike Fighter



# JOINT STRIKE FIGHTER



## VISION

BE THE MODEL ACQUISITION PROGRAM FOR  
JOINT SERVICE AND INTERNATIONAL  
COOPERATION

DEVELOP AND PRODUCE AN **AFFORDABLE**  
NEXT GENERATION STRIKE FIGHTER  
WEAPON SYSTEM AND SUSTAIN IT  
**WORLDWIDE**

The Next Generation Strike Fighter



# Current Logistics Structure

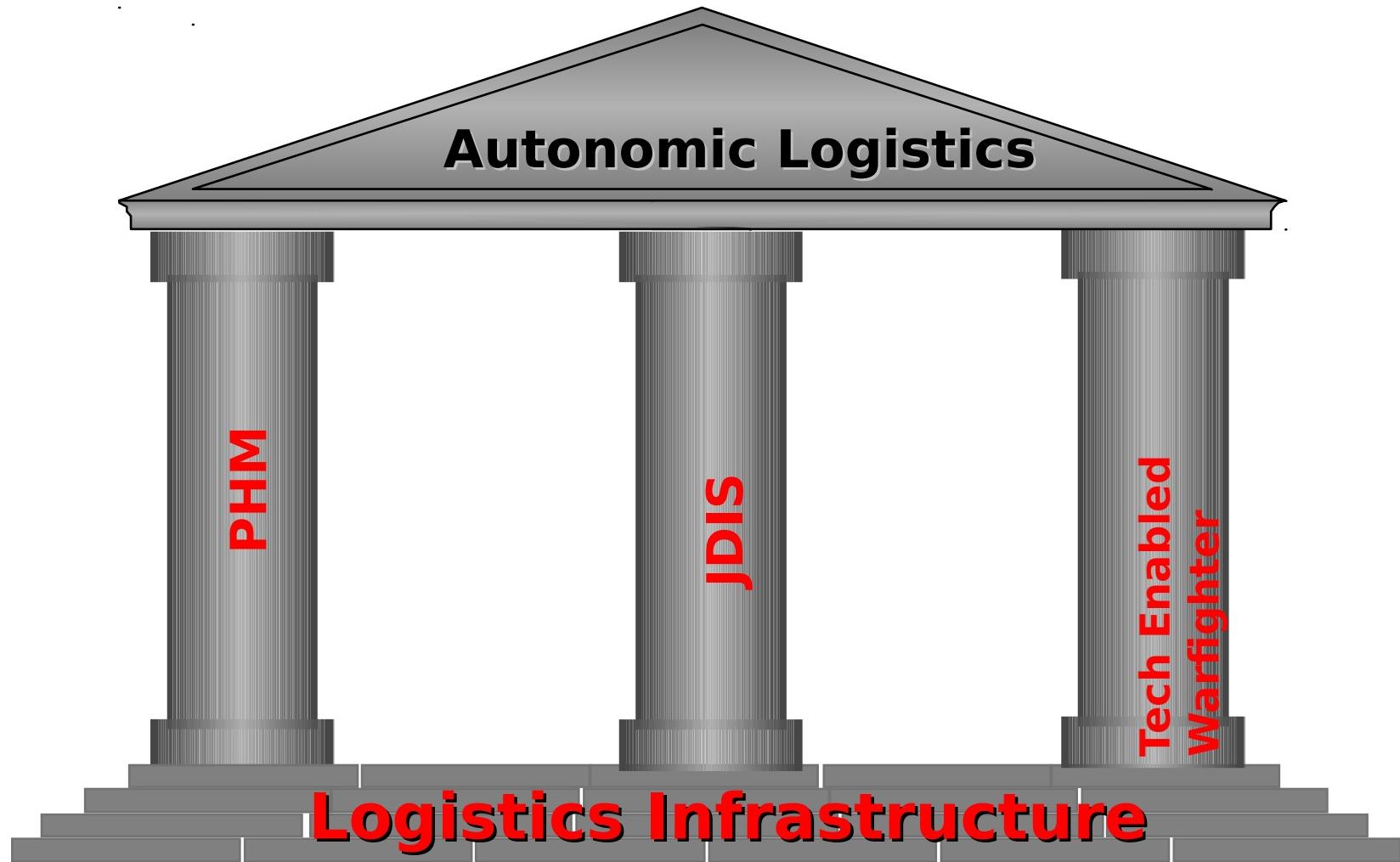
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**Too Large & Costly**



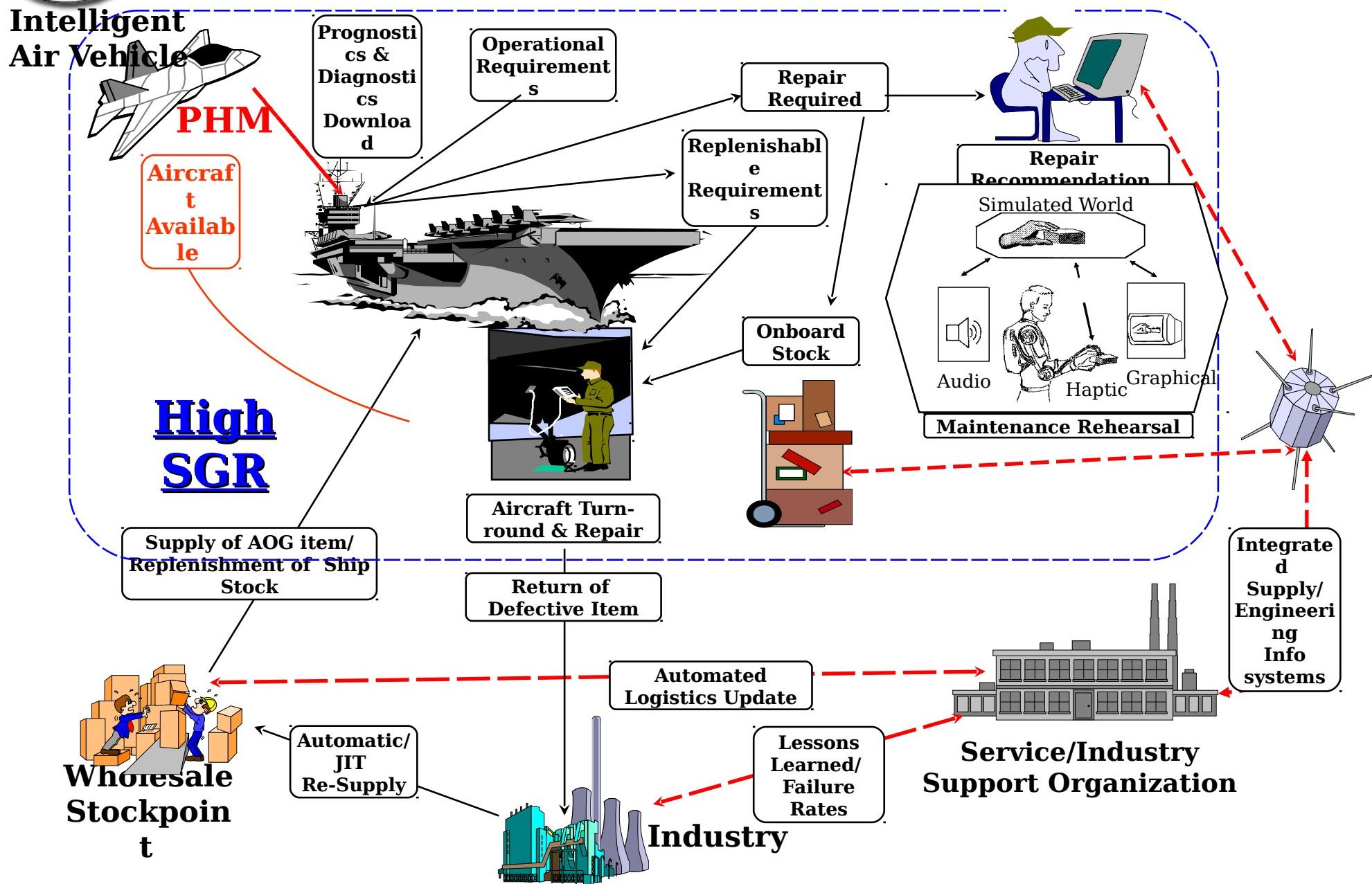
# Key Elements of Autonomic Logistics



Affordable, Survivable, Maintainable,  
Supportable  
**Operationally Available and Lethal**



# Autonomic Logistics Structure





# Prognostics and Health Management

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## What is it?

- Diagnostics - **is the process of determining the state of a component to perform its function(s)**
- Prognostics - **is predictive diagnostics which includes determining the remaining life or time span of proper operation of a component**
- Health Management - **is the capability to make appropriate decisions about maintenance actions based on diagnostics/prognostics information, available resources and operational demand.**



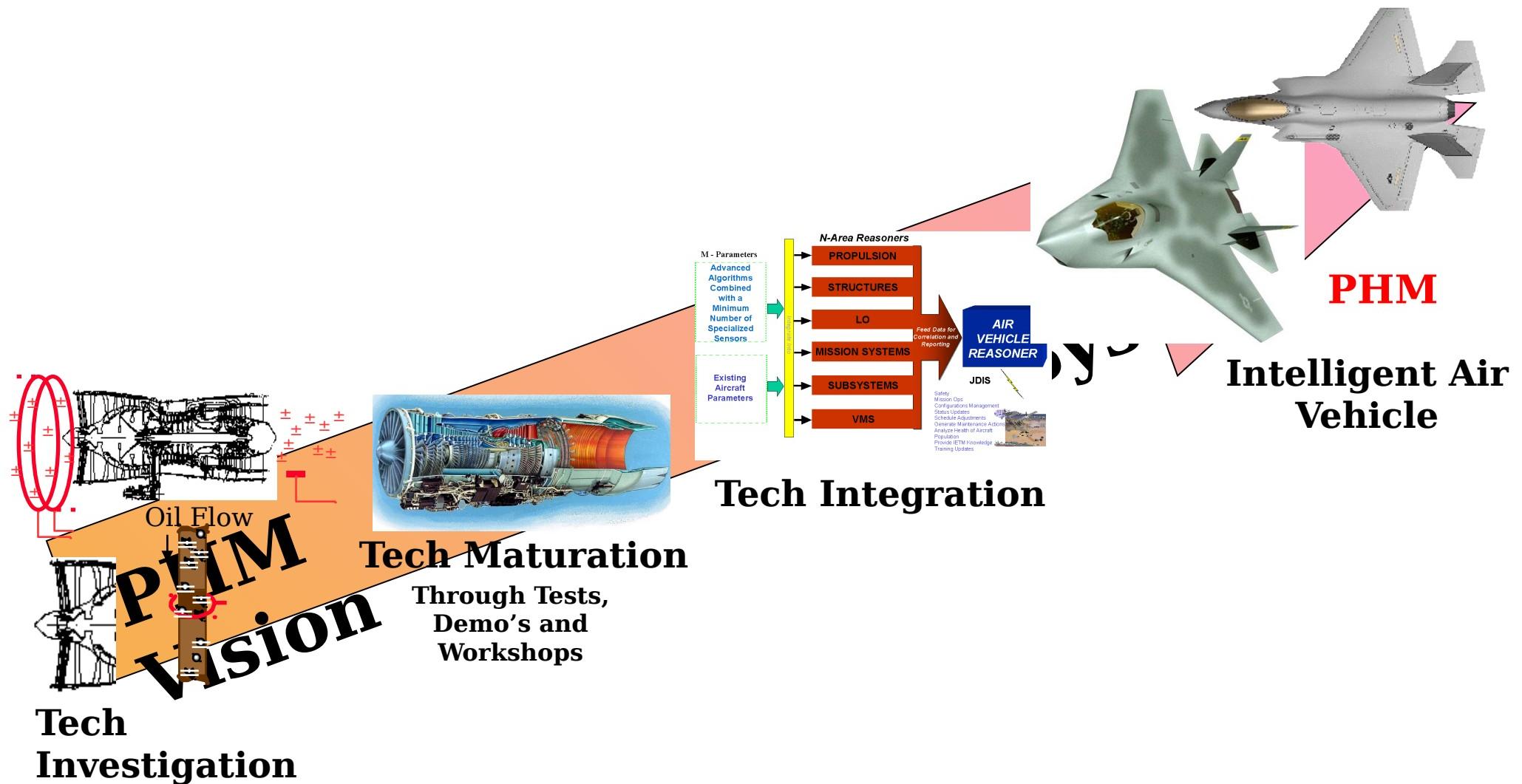
# Goals of PHM

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- **Enhance Mission Reliability and Aircraft Safety**
- **Reduce Maintenance Manpower, Spares, and Repair Costs**
- **Eliminate Scheduled Inspections**
- **Maximize Lead Time For Maintenance and Parts Procurement**
- **Automatically Isolate Faults to 1 LRC**
- **Eliminate CNDs and RTOKs**
- **Provide Real Time Notification of an Upcoming Maintenance Event at all Levels of the JSF Logistics Chain**



# PHM Maturation Strategy





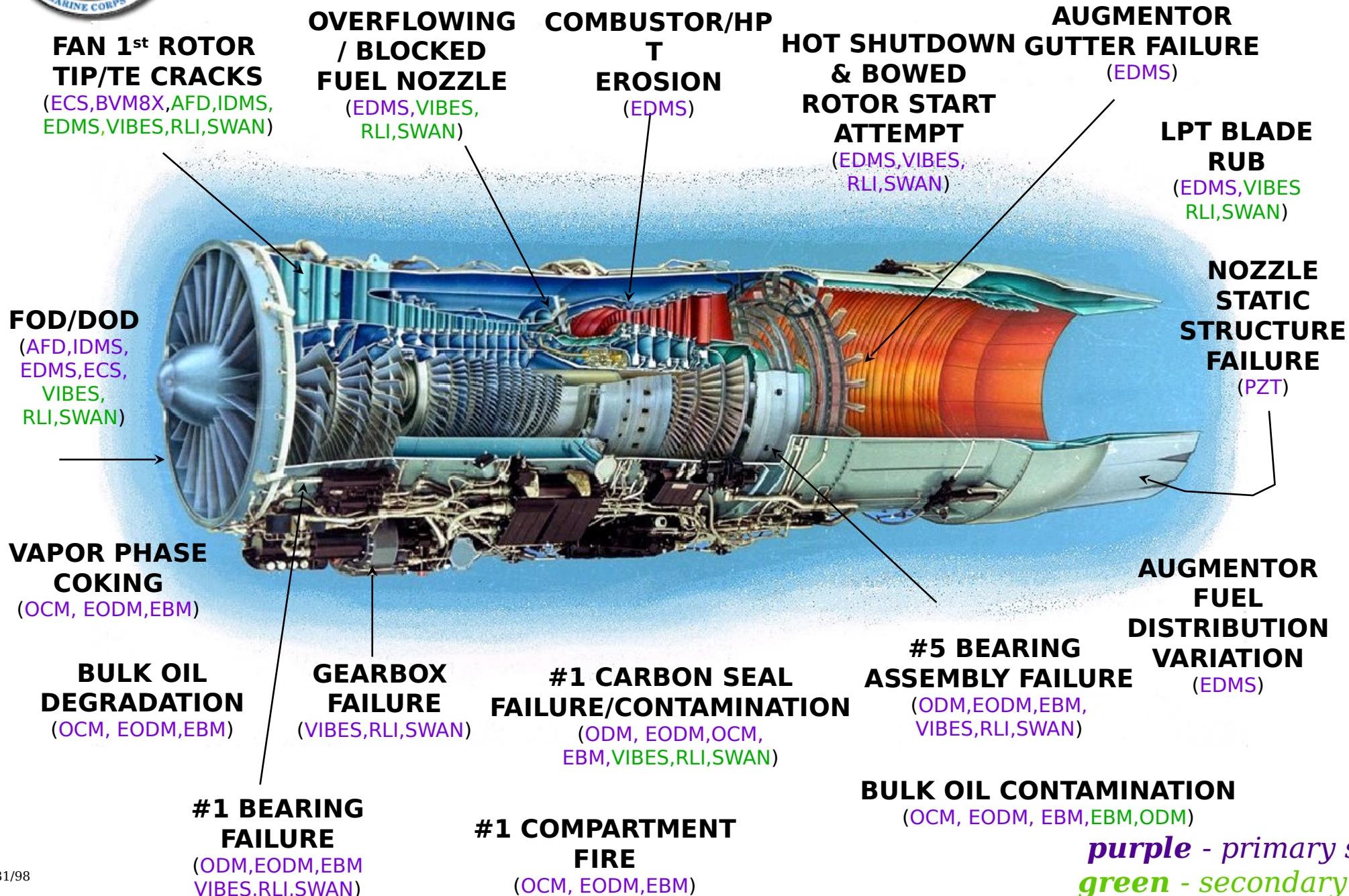
# CDP PHM Accomplishments

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- **Mature candidate technologies through special tests and programs**
  - SFET, Tech Maturation Efforts, Demonstrations, SBIR's, IMATE, CACE, Others....
- **PHM is designed into the air vehicle**
  - Designed down to all major subsystems
  - Architecture is well defined
- **PHM req'ts are reflected in JORD and JMS**
- **Req'ts and interface definitions defined**
- **Modeling environments developed**
- **PHM req'ts flowed to subsystem suppliers**
- **PHM maturation plans through E&MD**

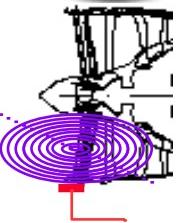
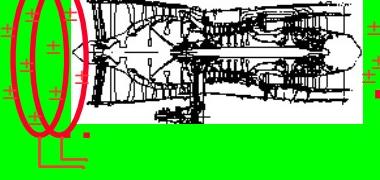
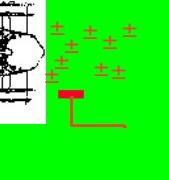
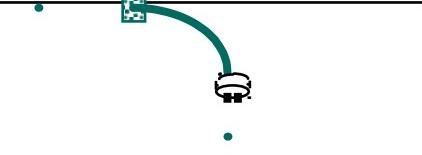
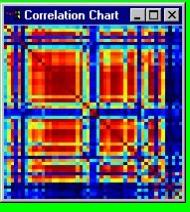
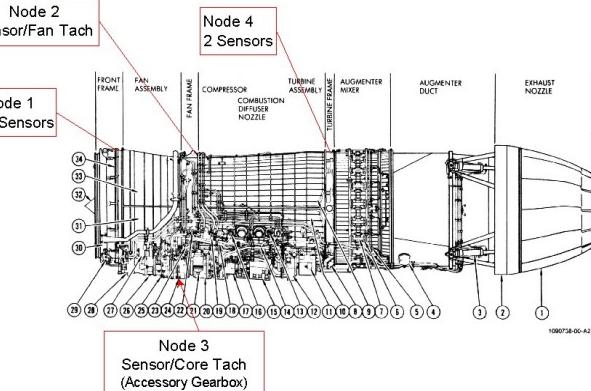
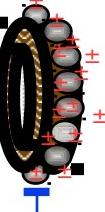
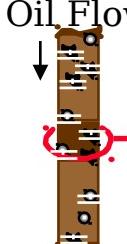
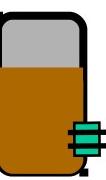


# F100 SEEDED FAULT ENGINE TEST PLAN





# PHM Technologies Evaluated During CDP

 <p><b>Acoustic FOD Detector (AFD)</b></p>	 <p><b>Eddy Current Blade Sensor (ECS)</b> GDATS</p>	 <p><b>Ingested Debris Monitoring System (IDMS)</b> Stewart Hughes Ltd</p>	 <p><b>Engine Distress Monitoring System (EDMS)</b> Stewart Hughes Ltd</p>	 <p><b>Piezoceramic Patch Crack Detection (PZT)</b> UTRC</p>
 <p><b>Beacon-Based Exception Analysis for Maintenance (BEAM)</b> JPL</p>	 <p><b>Robust LASER Interferometer (RLI)</b> Epoch Engineering</p>	 <p><b>MEMS Sensors</b></p>		
 <p><b>Electrostatic Bearing Monitor (EBM)</b> ExperTech</p>	 <p><b>Electrostatic Oil Debris Monitor (EODM)</b> ExperTech/SHL</p>	 <p><b>Oil Condition Monitor (OCM)</b> UDRI</p>	 <p><b>ICHM</b></p> <ul style="list-style-type: none"> <li>Communications</li> <li>Diagnostic Processor</li> <li>General Purpose Processing</li> <li>Signal Processing</li> <li>Signal Generation</li> <li>Power Interface/Generation</li> <li>Sensing</li> <li>Self calibration/Active Cancellation</li> </ul>	
 <p><b>Stress Wave Analysis (SWAN)</b> DME</p>				



# PHM Design Impacts

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- **PHM Architecture Significantly Improves Performance**
  - Increased fault detection/Fault Isolation
  - Reduces Ambiguities, Reduce False Alarms, Enables Use of Existing Sensors
- **PHM Has Influenced Virtually All Aircraft System Designs**
  - PHM Architecture Design Enables a Comprehensive Approach and Significant Growth Potential
  - Improve Accuracy & Fault Detection/Fault Isolation,
  - Incorporated Proven Demonstrated Technologies
  - Taken Advantage of Existing Parameters and Sensors; Minimal Weight/Cost Impacts
  - Takes Advantage of Advances in S/W Algorithms and Processing Technology, Reasoners, and a Few New Sensor Technologies
- **PHM Is One of the More Significant Integration Tasks**
  - Enhances the Influence of Supportability Impacts of Design
- **Boarded PHM Technologies Have Been Demonstrated, Tested, or Analyzed/Assessed as Low-Risk**
- **PHM Program Shows Potential For Significant Operational and Support Benefits**
  - Cost Benefit Analyses Defined Very Significant Savings
  - All Capabilities have to “buy their way on”

***PHM Technologies Integrated Into the Design  
Ensure A Capable, Affordable, Low-Risk Solution***



# PHM Redefines Design Criteria

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- Old
  - Safety and Supportability are a Function of Reliability, Redundancy, and the Support Concept ~ *Ensures*
- New
  - Safety and Supportability are a Function of Reliability, Redundancy, **PHM Capabilities**, and the New Support Concept ~ *Drives*

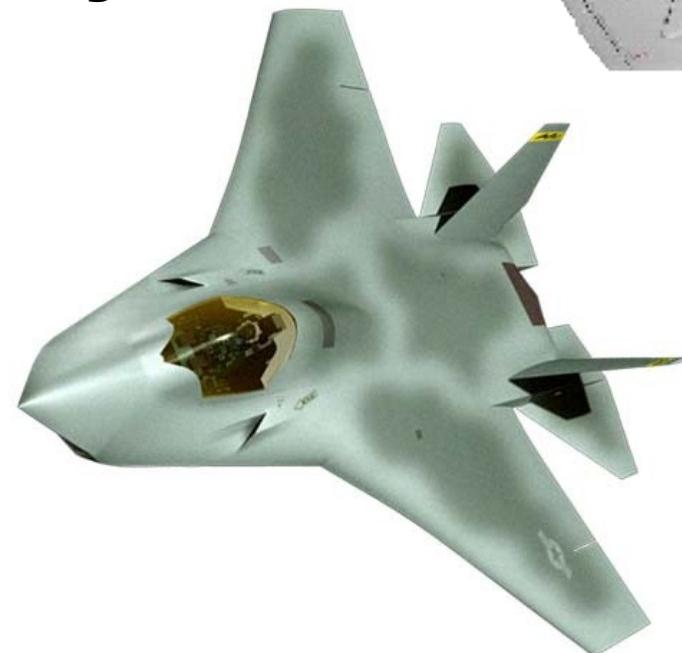
Autonomic Logistics Enables a Paradigm Shift



# PHM is Designed into the Air Vehicle

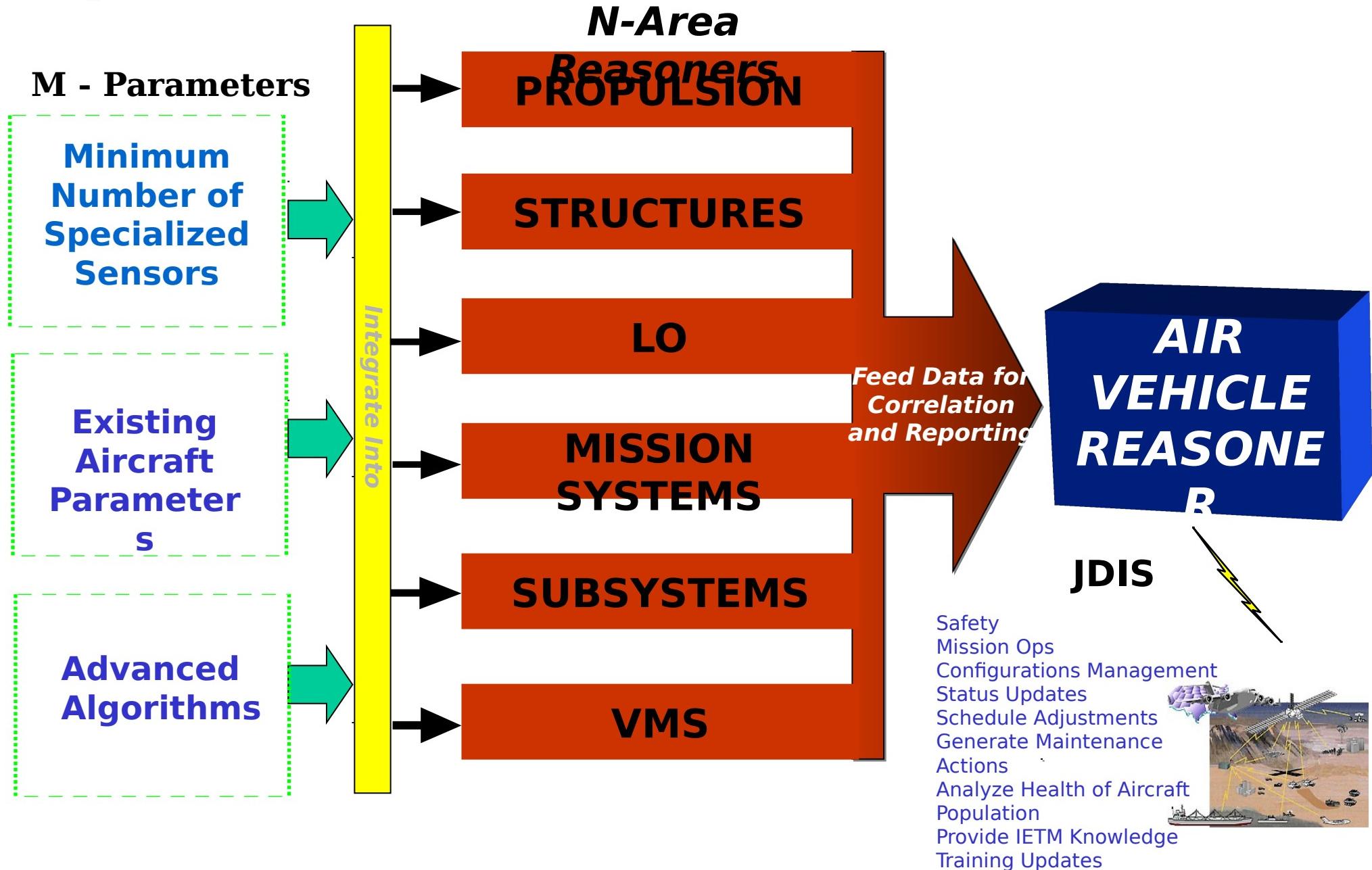
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- **Reflected in JORD and JMS Requirements**
- **Reaches across the entire airframe**
  - **Mission Systems**
    - FD/FI - In flight reconfiguration
  - **Structures**
  - **Signature**
  - **Propulsion**
    - Dual engine safety with single engine
  - **VMS**
    - Electronics Prognostics
  - **Subsystems**
    - Hydraulics
    - Fuel System
    - Electric Power System
    - APU
    - Drive Shafts
    - Etc...





# PHM Architecture





# E&MD Products

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- **Fully Functional PHM System at Initial Fleet Introduction**
- **Comprehensive PHM Capability on All Major Subsystems**
- **Demo's, Validated and Verified PHM Capabilities**
- **On-board PHM Hardware and Software Architectures Fully Integrated with the Aircraft Design**
- **Off-Board PHM Seamlessly Integrated with JDIS and On-Board PHM**
- **Any Appropriate Advanced Technologies Fully Capable and Prepared for Eventual Insertion at the Proper Time**

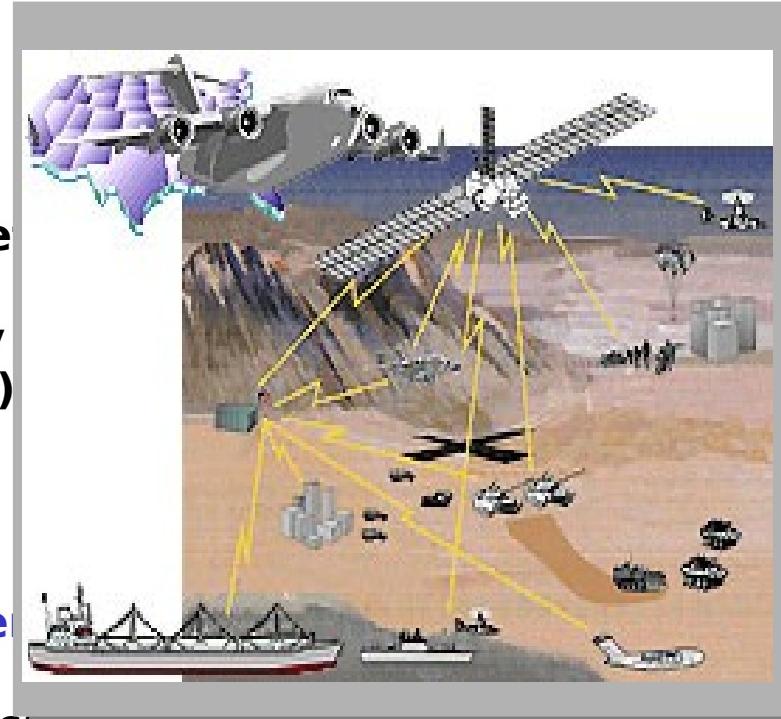


# JOINT DISTRIBUTED INFORMATION SYSTEM (JDIS)



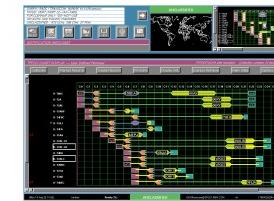
## Communications

- Web enabled
- Radio Frequency
- Infrared/Ultraviolet
- SATCOM
- Databurst Mayday (Black Box Data)



## Maintenance Management

- Web Interfaces
- Maintainer Identification
- Automatic Record of repairs
- Compatibility with legacy systems



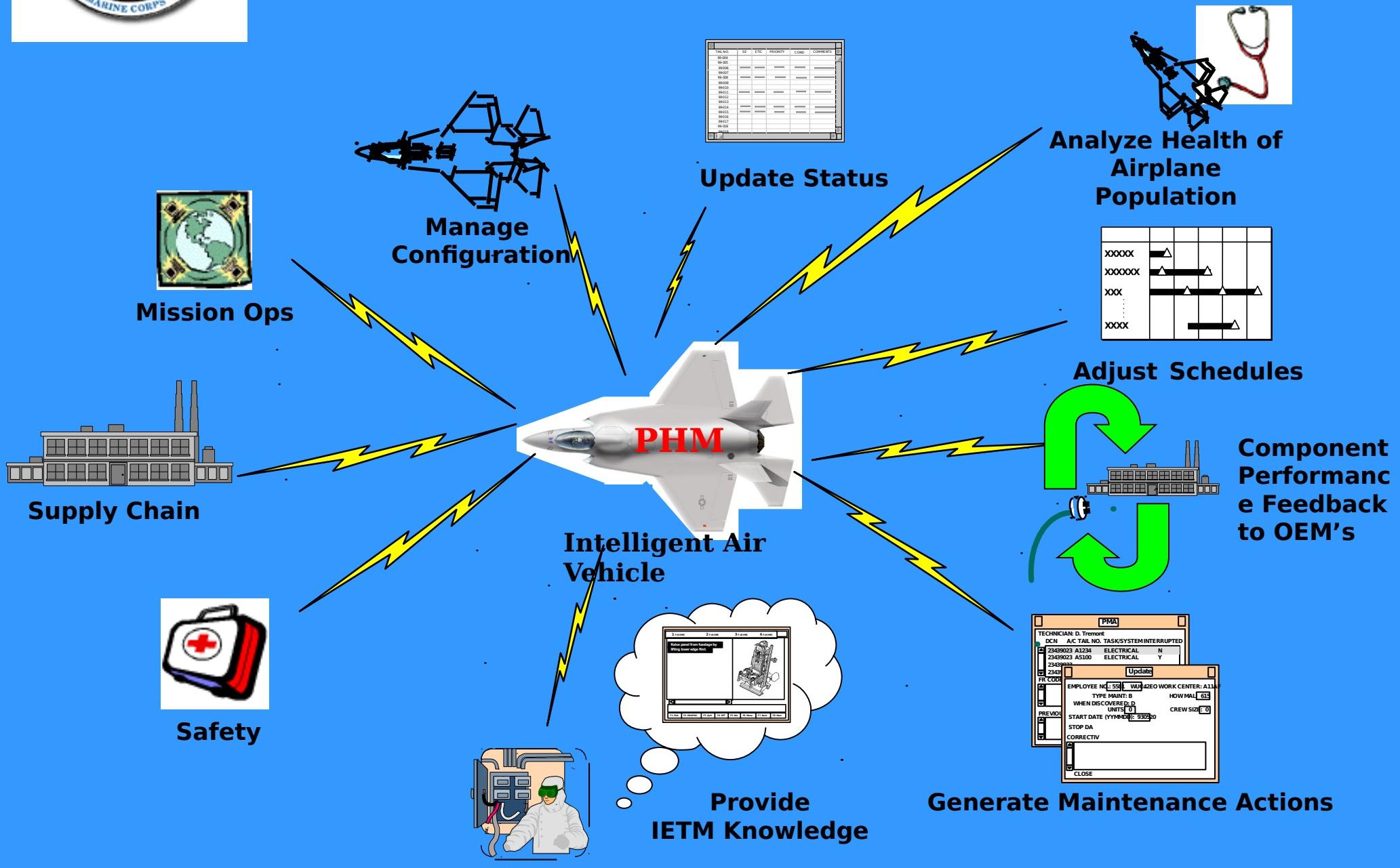
## Database Management

- Safety
- Mission Ops
- Configuration Management
- Status Updates
- Schedule Adjustments
- General Maintenance Activities
- Analyze Health of Aircraft
- Population
- Provide Interactive Electronic Technical Manual (IETM) Knowledge

**Intelligent, Connected Logistics Infrastructure**



# JDIS FUNCTIONALITY





# Technologically Enabled Warfighter



Interactive Electronic Technical Manuals



Electronic Classroom



Maintainer in the Loop



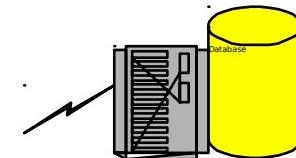
On-Line Support



Virtual Reality Haptic Feedback



Embedded Simulation



On-Line Maintenance Technical Manuals

## Technician Enhanced With Technology



# AUTONOMIC LOGISTICS SUMMARY

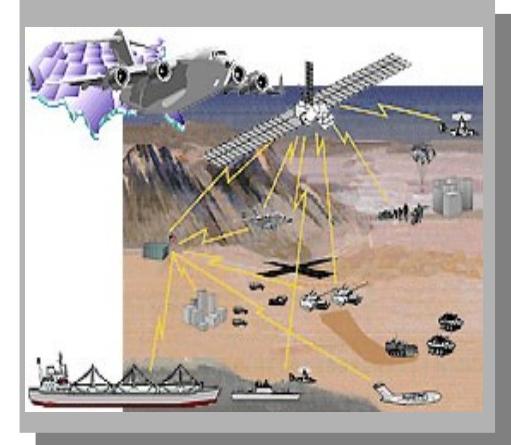


**PHM**

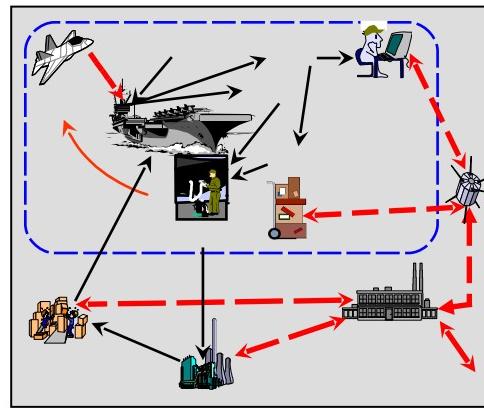
**Intelligent Air Vehicle**



**Technologically Enabled Warfighter**



**Joint Distributed Information System**



**Autonomic Logistics**

**By 2020, the JSF will comprise 75% of US Tactical Aircraft**

**Affordability is the only option**

***AUTONOMIC LOGISTICS WILL DELIVER***



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The Next Generation Strike Fighter